IS 4880-1 (1987): Code of practice for design of tunnels conveying water, Part 1: General design [WRD 14: Water Conductor Systems]

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Indian Standard

CODE OF PRACTICE FOR DESIGN OF TUNNELS CONVEYING WATER

PART 1 GENERAL DESIGN

(First Revision)

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BUREAU OF INDIAN STANDARDS
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TO
IS 4880 (PART 1) : 1987 CODE OF PRACTICE FOR DESIGN OF TUNNELS CONVEYING WATER

PART 1 GENERAL DESIGN

(First Revision)

[*Page* 3, *clause* **3.1**(j)] — Insert the following at the end:

k) Brittleness test ;

m) Stever's 'J' value tests; and

n) Abrasion test.

(*Page* 3, *clause* **4.1**) — Insert the following at the end:

'f) *Pore Pressure Observations* — Pore pressure meter for monitoring the pore water pressure around the tunnels.'

(*Page* 3, *clause* **4.4**) — Insert the following new clause after **4.4**:

'**4.5** Numerical tools should be used to carry out stress analysis using the laboratory and *in-situ* test results to predict the likely stress pattern and deformation around tunnels after excavation. The same shall be compared with the instrumentation observations on the tunnels and thereby analysis should be refined as construction progresses.'

(WRD 14)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CODE OF PRACTICE FOR DESIGN OF TUNNELS CONVEYING WATER

PART 1 GENERAL DESIGN

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0. FOREWORD

0.1 This Indian Standard (Part 1) (First Revision) was adopted by the Bureau of Indian Standards on 30 October 1987, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Divison Council.

0.2 For the alignment of tunnels and designs of tunnel supports and lining, the nature of soft or hard strata and its formation plays a vital role. It is necessary to know the general topography, the geology of the area, state of stress and other mechanical properties of the strata. For this certain topographical and geological investigations, *in-situ* and laboratory test, and observations are necessary. For certain locations where difficult working conditions are anticipated, more detailed investigations may be undertaken.

0.3 This standard has been published in various parts. Other parts of this standard are as follows:

- Part 2 Geometric design
- Part 3 Hydraulic design
- Part 4 Structural design of concrete lining in rock
- Part 5 Structural design of concrete lining in soft strata and soils
- Part 6 Tunnel supports
- Part 7 Structural design of steel lining

0.4 This standard was first published in 1975. The present revision of the standard has been taken up in the light of experience gained during the last few years in the use of this standard. In this revision, the clauses on '*in-situ* rock and tests' and 'instrumentation' have been modified to introduce the modern rock mass classification.

1. SCOPE

1.1 This standard (Part 1) covers the general requirements, like various types of investigations, tests and instrumentation of tunnel generally required for planning and designing of pressure tunnel section and supports.

2. INVESTIGATIONS

2.1 General — Records of any existing tunnels and other excavations in the vicinity including any information regarding old mine workings or old wells, should be sought and studied. Information should also be sought in historic records concerning flooding, avalanches, landslips, earthquakes, etc.

2.2 Topographical Surveys — Surveys for preparation of plans and aligning the tunnel should be carried out covering the area of tunnel alignment, after establishing adequate number of temporary bench marks with reference to the G.T.S. bench mark available in the vicinity. The survey shall be carried out in accordance with the provisions contained in IS : 5878 (Part 1)-1971*. Where movements along faults are suspected, local network of survey monuments shall be laid and observations made during construction period as also later during operation.

2.2.1 Preliminary investigations for aligning the tunnel should be carried out on available 1 : 50 000 Survey of India Topo Sheets. Once the general feasibility of the tunnel is established, detailed strip topographic maps along the tunnel alignment should be prepared to a scale 1 : 10 000 with 5 m contour interval. Width of the strip may be fixed on the basis of investigations, which shall be carried out more intensely at locations where certain local geologically adverse features like major shears, thrusts,

*Code of practice for construction of tunnels: Part 1 Precision survey and setting out.

faults synclines, etc, exist or where exposed rock is encountered and where the rock cover is less than the internal water pressure at that location. The strip width shall be commensurate with the internal water pressure on either side of alignment and also up to contours corresponding to tunnel grade indicating location of adits where necessary. At portal faces, the contour interval should be reduced to 2 m.

2.2.2 Wherever possible, aerial (photographic) survey should be carried out and the stereoptic coverage should extend for at least 3 km on either side of the possible foreseen limits of the tunnel alignment. This would facilitate to pinpoint those areas that require surface and subsurface investigations for a detailed assessment. If infra-red aerial photography is used, it would facilitate to delineate hot water bearing zones in bed rock.

2.3 Geological Investigations — Geological investigations should be carried out with sophisticated instruments, some of which are listed in **4.1**. If the area has been aerially photographed, such data should be studied.

2.3.1 The geological investigations should be carried out to determine:

a) Origin and type of rock along the alignment and study of regional geological maps of the area, if available;

b) Geological section along the tunnel alignment giving rock types and their disposition; location and attitude of all structural features of rock such as faults, thrusts, joints, dips, strikes and other geological features including pattern, extent and contents of fissures; presence of water in small or large quantities and their probable pressure at tunnel grade, etc;

c) Any geological feature which may affect the magnitude of rock pressure to be anticipated along the proposed alignment;

d) Cover on the tunnel, position of subsurface rock and overburden contacts;

e) Physical, mechanical and strength properties of rock to determine supporting arrangements and also resistance to driving tunnel through rock (if tunnelling with a mole is proposed); and

f) Hydrological data and information regarding location, type and volume of water and injurious or troublesome gases contained in subsurface strata around tunnel grade.

2.3.2 The geological data should be developed through a comprehensive geological investigation which includes:

a) *Detailed geological mapping* — Detailed geological mapping to know the rock formations, locations and altitude of structural features such as folds, faults, joint pattern, etc, to plan drill holes;

b) *Subsurface exploration* — Few cored bore holes should be taken at suitable locations along the alignment of tunnel as suggested by geologist. The number of bore holes depends upon the length of tunnel, rock cover over tunnel grade, number of adits available and geological features likely to be met with. However, the minimum number of bore holes as adjudged to be necessary by an experienced engineering geologist in consultation with design engineers should be provided. For proper determination of rock quality designation (RQD) (*see* **3.2.3**), the bore holes should be drilled with *NX* size and larger size only and not that *BX* or smaller sizes. The core samples of each bore hole shall be preserved and logged by an engineering geologist. Bore holes shall avoid, as far as possible, intercepting tunnel bore, particularly in water bearing strata, and shall be properly backfilled preferably with concrete;

c) *Geophysical investigations* — This type of investigation is helpful in establishing the rock-soil boundary, in delineating fault and shear zones, other geological structures and similar phenomenon. This investigation is also used in evaluating rock mass quality by determining *in-situ* modulus of elasticity;

d) *Television investigation of bore holes* — If possible, the walls of bore holes may be examined by television bore hole cameras. This method facilitates in studying the depth of altered rock, location and determination of the altitude and character of shear zones, joints fractures, foliations and bedding planes, assessment of rock condition above and below the water table, identification of rock types and other visually detectable geological characteristics of in-place rock prior to excavation;

e) *Exploration drifts* — Drifts should be provided at portals or at adit points. These are most accurate means of determining the geological conditions in tunnelling and for conducting *in-situ* rock tests.

2.3.3 Geological investigations should be continued during construction not only in the interest of checking design data but also for ascertaining the tunnelling methods and predicting tunnel conditions ahead of tunnel face to minimize surprises.

3. TESTS

3.1 Laboratory Tests — The core samples collected from the bore holes shall be classified and specimen from each group shall be tested to determine the following physical properties:

a) Specific gravity,

b) Modulus of elasticity (static and/or dynamic),

c) Poisson's ratio,

d) Tensile strength,

e) Compressive strength (dry and wet),

f) Triaxial shear strength,

g) Hardness of rock,

h) Swelling index (in case of soft argillaceous rocks), and

j) Porosity, grain size and cementing material for sand stones and similar rocks.

3.2 *In-situ* Rock Tests

3.2.1 The data obtained from field and laboratory tests shall be substantiated by *in-situ* rock tests. When a cavity is formed in the rock mass, the *in-situ* rock stresses are altered for some distance around the opening. *In-situ* rock tests are carried out to evaluate:

a) *In-situ* rock characteristics like shear strength parameters (*C* and *l*), compressive strength and deformation modulus preferably by Goodman Jack;

b) Deformation of rock around opening;

c) Rock load on supports — temporary and permanent; and

d) The tests shall be carried out in two directions at right angles to each other in case of laminated rock structures—one parallel to and the other at right angles to the dip and strike of rock. Plastic fields shall be determined by repeated loading and unloading tests.

3.2.2 The information obtained from **3.2.1** is required for providing supporting system in tunnel and design lining. These are to be obtained by installing instruments described in **4.1**.

3.2.3 From the bore hole logs, rock quality designation (RQD) should be determined. Geotechnical and geological data should be collected with a view to enable modern rock mass classification [*see* IS : 11315 (Part 11)-1985*].

4. INSTRUMENTATION

4.1 Systematic instrumentation is to be done in all major tunnels under construction to monitor the behaviour of supports and the rock. Such a study may be started from the very start of the tunnel. The instruments should be installed at the time of installation of the supports. The following may be done. The instrumented section should be so dispersed as to cover statistically differing rock conditions:

a) *Closure Observations* — Tunnel closure should be observed at random interval throughout the length of the tunnel;

b) *Bore-Hole Extensometer* — Multipoint bore-hole extensometer should be used to know the deformation in the rock around the tunnel opening. The observations will help in ascertaining the shape and size of the plastic (broken) zone. A minimum of three, that is, one horizontal, one vertical and one at 45° to the horizontal per section should be used;

c) *Load Observations* — Rock load coming on the steel supports should be monitored by installing load cells on ribs. A minimum of three per section should be used;

d) *Contact Pressure Observations* — Pressure cells should be placed at the intervals of the supports and the rock surface to measure rock pressure and internal water pressure. The pressure cells should not be placed at preferably less than 60°; and

e) *Strain Observations* — Should be done by embedding strain meters in concrete lining for the measurement of stress in the lining.

4.2 The instruments mentioned in **4.1** may be provided at more than three sections or at the typical representative reaches met with while excavating. The range of instruments to be installed depends upon rock cover, internal pressure and geological features and properties of rock mass and should be fixed after due analysis. Instrumentation may be done in the drifts which are made during investigation so that the data can be made available for design of supports and lining during execution of the work.

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*Method for the quantitative descriptions of discontinuities in rock masses: Part 11 Core recovery and rock quality.

4.3 Suitable instruments may be used for construction and post-construction stages.

4.4 The observations shall be taken in accordance with the format and frequency suggested by the experts.

5. GENERAL DESIGN

5.1 Investigations as detailed in **2**, **3** and **4** can be used in general designing of the tunnel which can be proceeded with as laid down in the following six parts of this code:

Part 2 Geometric design,

Part 3 Hydraulic design,

Part 4 Structural design of concrete lining in rock,

Part 5 Structural design of concrete lining in soft strata and soils,

Part 6 Tunnel supports, and

Part 7 Structural design of steel lining.

Amendments Issued Since Publication

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